

RISK MAPPING OF PESTICIDES: THE DUTCH ATLAS OF PESTICIDE CONCENTRATIONS IN SURFACE WATERS: WWW.PESTICIDESATLAS.NL

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SUMMARY

Many pesticides are being measured in surface water. To promote the use of monitoring data in the process of risk mapping, post-registration, and improvement of water quality, a free available Internet tool has been developed to present all measurements of pesticides in surface water on the level of individual active ingredients in a spatial framework: the Dutch pesticides atlas (www.pesticidesatlas.nl). With this communication tool one can easily get maps concerning where a pesticide is being measured, observed and possibly constitutes a problem over the years. Pesticide concentrations are being compared with environmental standards and maps can be made of each pesticide at a national level. The pesticide maps have been linked with GIS land use data. At present statistical correlations can be made between crop areas and pesticides concentrations in the water. Moreover, predictions can be made where a pesticide might be exceeding environmental standards. Policy makers, chemical industry (product stewardship), NGO's and farmers can use the maps as a tool for communication and improving environmental quality. The atlas is also being used to evaluate the effectiveness of pesticide policy over the years. In this contribution the methodological background of the pesticides atlas is presented.

INTRODUCTION

In the Netherlands pesticide concentrations in surface waters are monitored by a number of different regional water authorities, with results being amalgamated and reported periodically by different stakeholders. Until recently no attempt have been made to present the data at the level of individual active ingredients in spatial terms. Neither have the monitoring data been used to explore relationships between land use (crops) and/or pesticide use. Since the link with land use or pesticide use was missing, the Dutch Board on the Admission of Pesticides (CTB) could hardly use the monitoring data for the re-approval of active ingredients.

Geographic presentation of individual pesticide concentrations in the form of maps has several advantages compared with traditional (tabular) presentation (*cf.* Van 't Zelfde & de Snoo, 2003): 1) The maps show where a pesticide is monitored, the level at which it is observed and whether this level is problematical. 2) The maps can be used to review the quality of the current monitoring system. 3) Finally, the maps can be used to explore how pesticide levels relate to land use and as feedback to improve national pesticide admission procedures (post-registration).

Against this background, at the initiative of Leiden University's Institute of Environmental Sciences (CML), and with solid support from an array of other organisations a study was conducted to assess the potential for presenting

such maps in the form of a Pesticide Atlas of the Netherlands. Aims of the study were to provide an insight into pesticide contamination of Dutch surface waters and to investigate:

- where a pesticide is being measured, observed and exceeding an environmental standard,
- how to improve the regional monitoring systems,
- and whether it is possible to link pesticide concentrations with land use data (related to the re-approval of pesticides).

Today, Dutch pesticide monitoring data have now been processed into a free available graphic format accessible on-line (www.pesticidesatlas.nl) and in this paper we will provide a general description and methodological background of this information and communication tool.

SET UP PESTICIDES ATLAS

General

All the pesticide monitoring data used in the Pesticides Atlas are derived from the water quality databases owned and administered by 28 water boards responsible for monitoring pesticides in Dutch surface waters, with prior checks being made on data quality and quantity. The main feature of the pesticides atlas is a large set of maps (with grid cells of either 5×5 km or 1×1 km) and histograms reviewing measured concentrations of individual pesticides in relation to environmental quality standards in force in the Netherlands: the European drinking water standard, the Maximum Tolerable Risk (MTR) and the pesticide authorization standard applied by the Dutch Board for the Authorization of Pesticides (CTB). The first of these standards has been set at 0.1 µg/l, for almost each individual pesticide, while the other two are pesticide-specific and vary. The site also contains overviews for the Netherlands as a whole, in the form of histograms and graphs. Finally in the pesticides atlas the pesticide data are linked to land use data. Does a correlation exist between land use area and the concentrations in the water or even the exceeding of an environmental standard? The information about land use is also used to make predictions about the possible water quality at sites where no measurements have been carried out.

Monitoring data processing and aggregation

To create the pesticide maps the raw monitoring data are first processed, aggregating them in a stepwise procedure. These raw data, i.e. individual measurements of a particular pesticide at a particular monitoring site at specific moments in time, have already been flagged as being either 'below' or 'above or equal to' the detection limit. Aggregation is carried out at the level of either: 1×1 kilometre grid cells, or 5×5 kilometre grid cells. In the case of the MTR standard and the pesticide authorization standard, monitoring data are aggregated in the form of the 90% percentile and in the case of the drinking water standard, data are aggregated in the form of the maximum-recorded value.

To include all relevant information in the ultimate assessment, information on the status of measured values relative to the detection limit is retained in the calculations as long as possible. This is done by carrying out aggregation separately for measurements 'below' the detection limit and for those 'above or equal to' it, with the two not being combined until after final assessment against standards. For the purpose of assessment against standards, at the 1×1 km or 5×5 km grid cell level, the monitoring data are aggregated as follows: 1) First, the individual data from each monitoring site are aggregated (as specified above) to yield an annual Figure. 2) At each monitoring site, the annual Figures are then aggregated over a two-year period. 3) Data from all monitoring sites are then aggregated at the kilometre cell level. 4) Finally, if so required, there is further aggregation at the 5×5 kilometre grid cell level. Eventually, aggregate values will be available for monitoring data 'below' the detection limit, on the one hand, and for those 'above or equal to' it, on the other.

Assessment monitoring data against environmental standards

For each grid cell in which monitoring data are available, this procedure will yield either one or two aggregate values. If there is just one value, it will be either 'below' or 'above or equal to' the detection limit (DL); if there are two, one will be 'below' the DL, the other 'above or equal to' it. In comparing aggregate values with standards, the following three situations may therefore arise:

1. If there is just one aggregate value and it is 'above or equal to' the DL, then this is the only value available. In this case we have an *assessable value*, which may or may not exceed the standard.
2. If there is just one aggregate value and it is 'below' the DL, again this is the only value available. One of two situations may then arise: 1) if the DL is 'below or equal to' the standard, we have an *assessable value* that does not exceed the standard in question; 2) if the DL is 'above' the standard, we have a *non-assessable value*, as there is no way of establishing whether or not the actual, unknown value exceeds the standard.
3. If there are two aggregate values, one 'below' the DL, the other 'above or equal to' it, there are three alternatives:
 - if the value 'above or equal to' the DL exceeds the standard, only this value is used: we then have an *assessable value* that exceeds the standard;
 - if both values are 'below or equal to' the standard, we have *assessable values* that do not exceed the standard;
 - if the value 'above or equal to' the DL is less than or equal to the standard and the aggregated value 'below' the DL exceeds that standard, we have a non-assessable value, as there is no way of establishing whether or not the actual, unknown value exceeds the standard.

This procedure yields, per compound, per monitoring period and per kilometre cell or 5×5 kilometre grid cell, a value for assessment against one or more standards.

Besides the spatial spread of the data, their spread in time was also examined. The data covered two years. To this end the average number of monthly measurements was recorded.

Comparing monitoring data with land use data

One of the key uses to which the Dutch surface water pesticide monitoring data can be put is to establish correlations with acreages of particular crops, to improve insight into possible causes of water contamination, and moreover, to predict where environmental standards might be exceeded in geographical areas where there is still no monitoring. For that purpose, the observed concentrations of the pesticides were analysed for correlation with acreages of dominant crops in The Netherlands (statistically analysed at the 1×1 km base using a non-parametric Spearman test). The following 24 major crop types were distinguished: asparagus, beans, cabbage, cereals, fallow, floriculture, flower bulbs, fruit culture, grassland, grass-seed, green manure, hemp, leaf vegetables, leek, maize, onions, potatoes, perennial garden plants, silviculture, strawberries, sugar beet, tree nurseries, vegetables and other arable crops. The geographical crop data per 1×1 km of the different years were derived from the database of the 'National Environmental Indicator (NEI) for Pesticides' of the National Institute of Public Health and Environmental Protection (RIVM) and Alterra (Information source LGN en CBS). To establish the relations between transgression of quality standards and crop acreage, all assessable measurements were statistically analysed. The aim here is to assess the extent to which transgressions of pesticide authorization standards are associated with higher acreages of any particular crop(s) than dictated by the laws of probability (non-parametric Mann-Whitney U-test).

Pesticide concentrations in un-sampled areas were predicted by means of regression analysis, taking pesticide concentrations as response variables and crop acreages as explanatory variables, both logarithmically transformed, and using only monitoring data above the detection limit. In this way concentrations were predicted in grid cells for which no monitoring data are available.

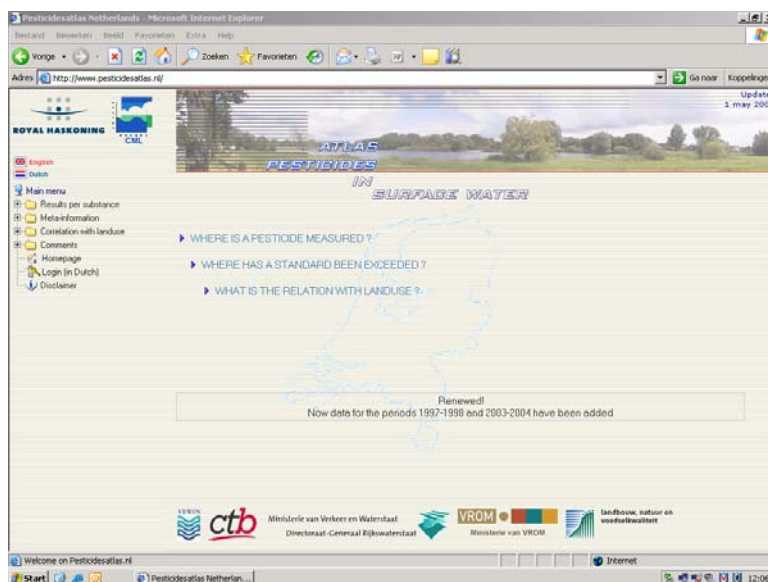


Figure 1. Homepage of www.pesticidesatlas.nl

RESULTS

Data quantity

Today all pesticide measurement data of the periods 1997-2004 has been gathered and analysed. The data are being presented at the Internet for every 2-year period (www.pesticidesatlas.nl, Figure 1). The number of active ingredients and the number of locations where the measurements are being carried out are shown in Table 1. From this table it is clear that for every period data of about 200 active ingredients are available. The number of locations has been increased over time. Of all active ingredients the number of measurements varies strongly. Totally for every period there are about 150.000 measurements available. In Figure 2 the geographical variation in the number of pesticides measured through the Netherlands is being illustrated. From this example with about 500 filled 5×5 km grid cells it can be concluded that in most cases at least 10, and in many cases up to more than 50 active ingredients are being measured.

Table 1. Overview of the quality of the pesticide data in the database (1997/1998 – 2003/2004)

	No. active ingredients	No. locations
1997/1998	199	512
1999/2000	187	717
2001/2002	216	781
2003/2004	291	877

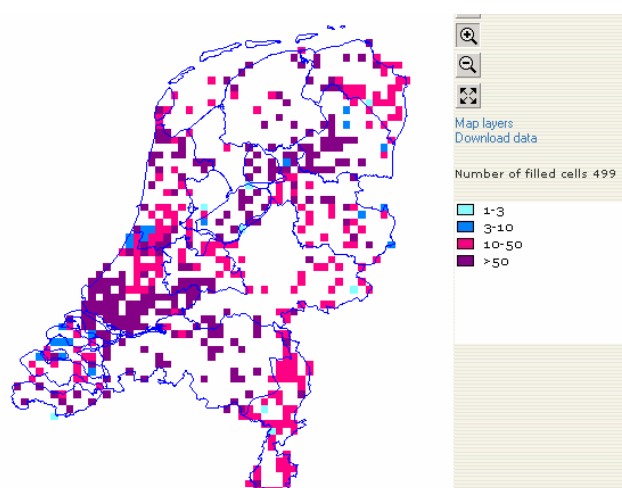


Figure 2. Number of pesticides measured per 5×5 km (2003-2004)

Pesticide monitoring data and environmental standards

In the pesticide atlas some overall information is being presented of all pesticides combined. For example data are shown about the percentage of locations where an environmental standard is being exceeded during the year (Figure 3). Figure 3 illustrates that in The Netherlands the European drinking water standard ($0.1 \mu\text{g/l}$) is being exceeded on at least 30% of the locations in all months of the year. It is remarkable that pesticide concentrations were also above this standard during the winter period, because in this period in most crops hardly any pesticides are used. The percentage of locations where the pesticide authorisation standard is being exceeded is much lower (max. 14%, Figure 3). The overall information about the pesticide concentrations is also geographically presented. This is shown in Figure 5. Here the combined European drinking water standard has been taken ($0.5 \mu\text{g/l}$) has been taken as an example, for two different time periods. In this way the overall environmental quality of surface water can be evaluated. From Figure 4 some environmental hot spots can be identified.

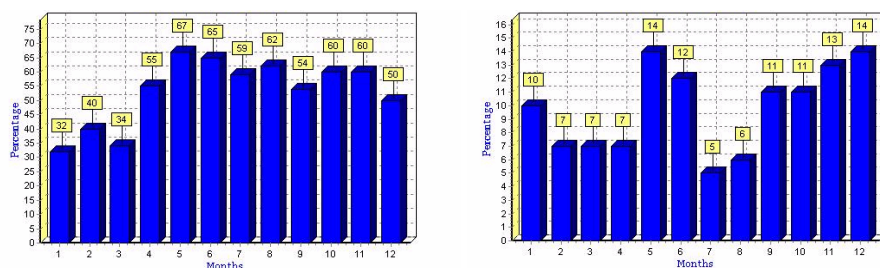


Figure 3. Percentage of locations exceeding an environmental standard during the year (2003-2004): left side European drinking water standard (0.1 µg/l), right side authorization standard

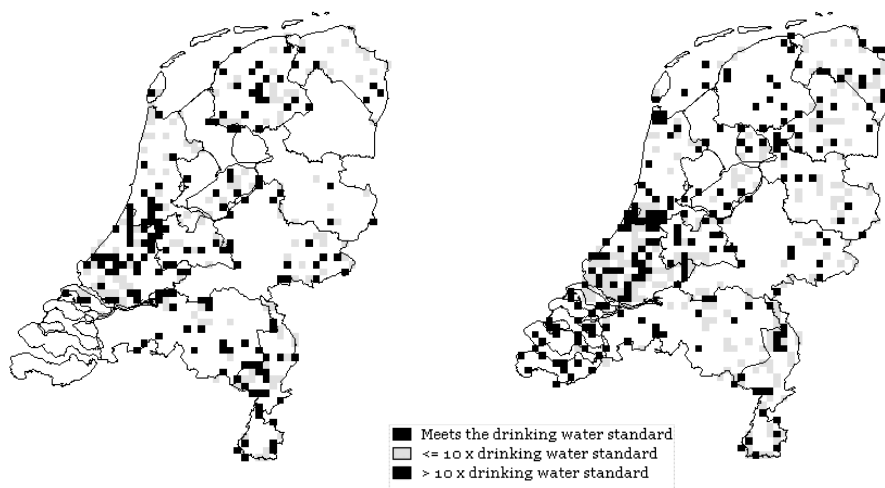


Figure 4. Percentage of locations exceeding the combined EU drinking water standard (0.5µg/l) during the year. Left side: 1997/1998, right side: 2003-2004 period.

However, the core business of the Internet tool is the information on the level of separate active ingredients. For each compound there is information given about the number of measurements, the number of locations, and most important where the compound has been found and exceeding an environmental standard in surface water. An example of such a map is given in Figure 5 (left side), showing the results for the compound carbendazim at a 5×5 km scale level and relating the monitoring data to the Maximum Tolerable Risk (MTR). At present there are about 5000 maps available at the Internet, showing such type of results for about 200 pesticides, for the three environmental standards, for different time periods and two different geographical scale levels.

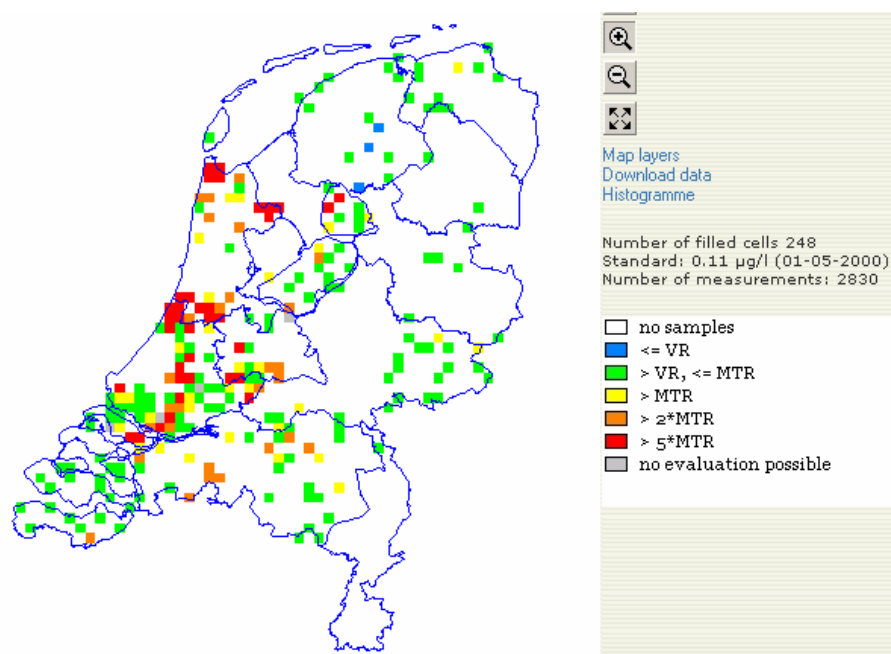


Figure 5. Carbendazim monitoring data (2003-2004) related to the Maximum Tolerable Risk (0.11 µg/l), VR = 0.11 ng/L (quality criterion as given in November 2005)

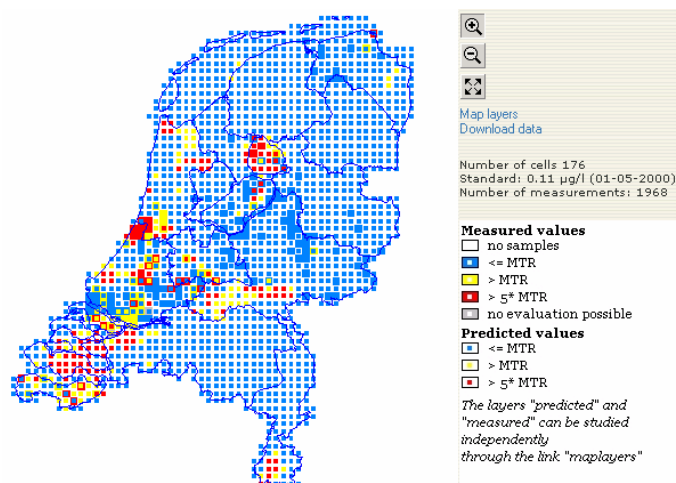
Pesticide monitoring data and land use

As outlined in the set-up of the research, the recorded environmental pesticide levels and the exceeding of environmental standards can also be linked with land use data by using statistics. In Table 2 an example is given of carbendazim (transgression of the Maximum Tolerable Risk) and land use data. From this table it is clear that there is a statistical significant relation between the crop area of greenhouse crops, flower bulbs, horticulture and the exceeding of the MTR for this specific pesticide. It is also mentioned that in one occasions (horticulture) the statistical relation is stronger than expected: a kind of alert for misinterpretation. This type of warnings is given for example when there is a little use of the pesticide in a certain crop (kg/ha) but still a significant relation. Finally, in the pesticides atlas also the pesticide concentrations related to the environmental standards in un-sampled areas are predicted based on the land use data. This is highlighted in Figure 6, where the predicted values for carbendazim are given for every 5 specific pesticide. 5 grid cell of The Netherlands. In this case several areas could be identified where carbendazim might be a problem in surface water.

Table 2. Transgression of Maximum Tolerable Risk standard of carbendazim related to land use

Contributions of crops to quality standard transgression for carbendazim in surface water, by significance class, for the Netherlands as a whole (measurements 2003-2004 monitoring data). Number of measurements = 377, of which 162 transgressions.

CROP	SIGNIFICANCE	WARNING
greenhouse crops	very strong	
flower bulbs	very strong	
floriculture	very strong	correlation much stronger than expected
fruit-growing	weak	
cabbage etc.	not quite significant	
onions		
leek		
cereals		
tree nurseries		
sugarbeet		
asparagus		
potatoes		

**Figure 6.** Measured and predicted values of carbendazim related to the Maximum Tolerable Risk standard

CONCLUSIONS

In the Netherlands environmental pesticide levels in surface water are a serious problem. Pesticides are to be found in every compartment of the environment, with standards regularly being exceeded (De Snoo & De Jong, 1999). As part of wider government policy to improve environmental quality, Dutch pesticide policy seeks to reduce pesticide use as well as emissions to the environment since the last 15 years (e.g., Multi Year Crop Protection Plan, 1991). With the development the pesticides atlas at the Internet, today a wide range of actors such as policy makers, regulators, farmers, chemical

industry, food industry and NGO's can have a good visual impression of the geographic spread of pesticide concentrations in surface water in the Netherlands. The pesticide maps give relevant information about where and when is a pesticide measured, found and exceeding an environmental standard. Based on this type of information not only monitoring systems of water authorities can be improved (measurements at relevant sites etc.), but the pesticides atlas might be used for evaluating environmental policy over time as well.

Since the release of the Pesticides Atlas on the internet, it is shown that in many cases pesticides concentrations and transgression of an environmental standard can be linked with land use data, the maps can be used also in the registration process. On the one hand as a tool for post-registration of individual pesticides on the Dutch market (re-approval) and on the other hand to improve and validate the models used for estimating the environmental concentration of pesticides in surface water (for example the National Environmental Indicator, <http://www.nmi.alterra.nl>). For industry the instrument might be useful to benchmark their products and communicate with farmers (product stewardship), or even to evaluate their total company performance.

Finally, the pesticides atlas might also be used for monitoring schemes under the EU Water Framework Directive. In this context in principle other (priority) substances such as heavy metals can be included as well, and the chemical data can also be linked with ecological data sets concerning the presence of aquatic flora and fauna.

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